4.0 MODELING RESULTS

This section discusses the results of estimating the fixed effects described in Section 3. These results are based entirely on the sampling results obtained in the CAP Study. The assessment of abatement efficacy presented here is based on a comparison of levels in abated houses with levels in unabated houses previously identified as being relatively free of lead-based paint, and not on a comparison of post- to pre-abatement lead levels. Therefore, this is an indirect assessment. Comparisons of pre-abatement lead levels with the results observed in the CAP Study are discussed in Section 7, along with other study results.

Included in this section are estimates of the differences in lead loadings, lead concentrations, and dust loadings among houses with different abatement histories — primarily abated vs. unabated and encapsulated/enclosed vs. removal. This is followed by a discussion of the observed variability between houses, rooms, and sampling locations.

Effects of other specific abatement factors are also presented here, including total abatement square footage, (interior and exterior), specific removal method applied (chemical stripping, heat gun, etc.), and differences among houses abated by different contractors. In addition, systematic effects of non-abatement factors are estimated. These include ownership factors such as age of the house, and questionnaire information, such as

- occupations of residents
- ages of occupants
- measures of cleanliness
- activities of occupants
- ownership.

Some factors were associated with differences at the sample level. These include:

- Substrate type and condition
- XRF measures taken prior to abatement
- Sampling deviations.

These factors were controlled for in the analysis and their impacts were estimated. Some variables, such as XRF measures taken prior to abatement, were strongly correlated with the primary design abatement variables. As discussed in Section 3, these were adjusted so that they would not mask the effects of abatement.

4.1 SUMMARY OF MODELING RESULTS

A summary of the primary results discussed here is presented in Tables 4-1 and 4-2. Table 4-1 presents geometric mean lead loading, lead concentrations, and dust loading for each type of sample collected, along with estimates of the differences between abated houses and unabated houses, and estimates of the differences between E/E houses and removal houses. Table 4-2 provides estimates of the differences in these responses between unabated rooms of abated houses, and abated rooms of the same houses. The information in these tables is supported with further detail in Section 4.2.1.

The indirect assessment of abatement efficacy found that abatement appears to have been effective, in the sense that there is no evidence that post-abatement lead levels at abated houses are significantly different than lead levels at unabated houses found to be relatively free of lead-based paint. There were two exceptions to this statement; however, both of these exceptions were anticipated and are logically explained. First, lead concentrations in air ducts were significantly higher in abated houses than in unabated houses; air ducts were not abated in the HUD Demonstration. In addition, lead concentrations in the soil outside abated houses were significantly higher at the foundation and at the boundary than corresponding lead concentrations outside unabated houses.

Table 4-1. Summary of Effects of Significant Primary Abatement Factors

Component	Obs.	Geometric Mean in Unabated Houses Based on Model Estimates			Ratio of Levels in Abated Houses[1] to Those in Unabated Houses			Ratio of Levels in E/E Houses to Those in Removal Houses		
		Lead Load µg/ft²	Lead Conc. µg/g	Dust Load mg/ft²	Lead Load µg/ft²	Lead Conc. µg/g	Dust Load mg/ft²	Lead Load µg/ft²	Lead Conc. µg/g	Dust Load mg/ft²
Dust										
Air Duct	86	76	332	202	4.70*	1.59*	3.11	3.99*	2.01*	1.80
Window Channel	83	1604	851	1857	0.86	0.98	0.88	0.54	1.46	0.37
Window Stool	113	38	416	92	1.84	1.70	1.09	2.51	1.77	1.42
Floor (Wipe)[2]	65							0.93		
Floor (Vacuum)	233	16	137	118	1.76	1.03	1.65	2.02	1.30	1.55
Interior Entryway	90	191	183	1055	1.05	0.85	1.19	1.15	0.95	1.24
Exterior Entryway	97	220	184	1152	2.24	1.19	1.95*	1.09	1.01	1.07
Soil										
Entryway (Soil)	109		126			1.48			1.26	
Foundation (Soil)	88		86			1.82*			0.81	
Boundary (Soil)	120		86			1.63*			1.27	

[1]For interior samples, these represent ratios of levels in abated rooms of abated houses to those in unabated houses.
[2]Floor wipe samples were only collected in abated units; the geometric mean in abated units was 11.3 after controlling for significant factors.
*Significant at 5% level.

Table 4-2. Ratio of Levels of Unabated rooms to those in Abated Rooms, both Within Abated Houses

Component	Lead Loading	Lead Concentration	Dust Loading
Air Duct	0.73	0.79	0.91
Window Channel	0.39	0.61	0.65
Window Stool	0.67	0.69	0.96
Floor (Vacuum)	0.56	0.87	0.65
Interior Entryway	1.63	1.28	1.31

However, soil was also not abated during the HUD Demonstration; and these higher lead levels might in part be due to differences in the age of these houses, since on average the abated houses in this study were 17 years older than unabated houses. As with the caveat stated above, these results must also be tempered by the fact that not finding a significant difference in lead levels at abated and unabated houses for all other building components and sampling locations does not prove that no such differences exist. The CAP Study was designed to detect two-fold differences between lead levels at abated and unabated houses under specified variance assumptions. For example, although the estimate of 1.76 for the ratio of lead loadings on floors in abated to unabated houses was not significantly different from one, the 95 percent confidence interval for this ratio was from about 0.87 to 3.5. That is, differences as large as a factor of 3 could not be judged to be statistically significant.

The CAP Study also assessed abatement by comparing encapsulation and enclosure methods versus removal methods. No significant differences among lead levels could be attributed to these two types of abatement methods, except for air ducts which, as stated above, were not abated. Air duct dust lead levels were higher in houses abated primarily by encapsulation and enclosure methods than in houses abated primarily by removal methods.

With regard to the second study objective, lead levels were found to vary greatly for different media and sampling locations. Minimum individual lead concentrations for most sample types were typically on the order of 10 µg/g except in air ducts and window channels where levels were at least 50 µg/g. Maximum individual lead concentrations were lowest for boundary and entryway soil samples (1073 and 1068 µg/g, respectively) and highest for window stool and window channel dust samples (48,272 and 45,229 µg/g, respectively). Minimum individual lead loadings for all sample types were typically only 1 to 4 µg/ft^2. Maximum individual lead loadings were lowest for floor dust samples (334 µg/ft^2 by wipe and 11,641 µg/ft^2 by vacuum) and highest for window channel dust samples (244,581 µg/ft^2).

Dust lead loadings were also evaluated in comparison with the HUD interim dust standards. Geometric mean lead loadings for both floors and window stools at both abated and unabated houses were found to be well below their respective HUD standards of 200 and 500 µg/ft^2. Geometric mean floor lead loadings were also below the EPA standard of 100 µg/ft^2 (EPA, 1994). In addition, for both floors and window stools, more than 75 percent of the samples collected in the CAP Study had lead loadings below their respective standards, in both abated and unabated houses. However, geometric mean window channel lead loadings at both abated and unabated houses were found to be well above the HUD interim standard of 800 µg/ft^2, and well over half of individual observations were above this standard, at both abated and unabated houses. These results indicate that perhaps even houses identified by XRF as lacking significant amounts of lead-based paint may have levels in the window channels in excess of the HUD standard.

One cautionary note should be mentioned concerning the interpretation of the differences observed in houses abated by the different methods. Most of the houses which had extensive abatement performed were abated by E/E methods. This may suggest that lead levels were often greater in the houses selected for abatement by E/E methods. In other words, the results presented here indicating that lead levels were higher after abatement by E/E methods may simply be a reflection of higher initial paint, soil, and dust lead levels in these houses. In most cases results were not significantly different.

4.2 DETAILED MODELING RESULTS

4.2.1 Analysis of Abatement and Random Effects

This section presents estimated effects of the various abatement factors considered in the study on lead loading, lead concentration, and dust loading for each sample type collected. These estimates are to be interpreted as having been corrected for other practical effects found to be significant (e.g., ownership, XRF measurements, cleanliness, substrate, etc.). Also described in this section is uncontrolled and unexplained random variation from house to house, room to room (or side to side), and within room/side for each sample type.

In many cases these numbers are lower than the total number of samples because of missing values of significant covariates. For instance, in some cases, the housing unit resident interviewed did not know the answers to some of the questionnaire items (e.g., ownership. cleanliness measures, etc.). Table 4-3 describes the number of samples used in the statistical analysis for each sample type, the number of samples used in fitting the model, and the percentage of samples excluded from the model fits. The number of missing values were fewer than 20 for most sample types. However, for foundation soil samples, 30 observations were excluded. For this sample type, the HUD Demonstration XRF measures were found to be a significant factor and there were several observations in the CAP Study for which there was no corresponding XRF measure available. There was also a substantial proportion of samples excluded from the model fit for air ducts.

Table 4-3. Summary of Samples Excluded from Model Fit Due to Missing Data on Covariates

		Number of Samples Analyzed*	Number of Samples Included in Model Fit	Percent Excluded
Dust	Air Duct	109	86	21
	Window Channel	98	83	15
	Window Stool	113	113	0
	Floor (Wipe)	67	65	3
	Floor (Vacuum)	238	233	2
	Entryway Interior	100	90	10
	Entryway Exterior	97	97	0
Soil	Entryway	109	109	0
	Foundation	118	88	25
	Boundary	120	120	0

*Excludes samples identified as outliers. See Section 8 for a discussion of the outlier analysis.

Effects of Primary Abatement Factors

Table 4-4 displays estimates of the effects of the primary abatement factors on lead loadings. Table 4-5 displays the estimated effects of the primary abatement factors for lead concentrations. Table 4-6 provides the corresponding results for dust loadings.

The first column provides the number of samples included in the model for each sample type. The second column in these tables contains the estimated geometric mean in houses which were not abated. The estimate is to be interpreted as the average lead loading in unabated houses when the covariates included in the model are fixed at the nominal levels of other significant factors. Effects of these factors are discussed in a later section. The log standard error of these estimates appears in parentheses below each estimate.

Figure 4-1 displays estimated geometric means in unabated houses by sample type for lead loading, lead concentration and

Table 4-4. Estimates[1] of Effects of Primary Abatement Factors on Lead Loading; Controlling for Significant Covariates

<table>
<tr><th rowspan="3">(1)
Sample Type</th><th rowspan="3">(2)
No. of Samples/ Denominator Degrees of Freedom</th><th rowspan="3">(3)
Geometric Mean in Unabated Units After Controlling for Effects of Significant Factors</th><th rowspan="3">(4)
Ratio of Levels in Abated Rooms of Abated Units to those in Unabated Units</th><th rowspan="3">(5)
Ratio of Levels in E/E Units to those in Removal Units</th><th rowspan="3">(6)
Ratio of Levels in Unabated Rooms of Abated Units to those in Abated Rooms of Abated Units</th><th colspan="3">Standard Deviation Estimates</th></tr>
<tr><th>(7)</th><th>(8)</th><th>(9)</th></tr>
<tr><th>Unit-to-Unit Log Standard Deviation</th><th>Room-to-Room Log Standard Deviation</th><th>Residual Log Standard Deviation</th></tr>
<tr><td>Air Duct (Vacuum)</td><td>86
(35)</td><td>76
(0.52)</td><td>4.70*
(0.61)
.016</td><td>3.99*
(0.68)
.049</td><td>0.73
(0.39)
.432</td><td>1.52
(0.86)
.002</td><td colspan="2">1.18</td></tr>
<tr><td>Window Channel (Vacuum)</td><td>83
(26)</td><td>1604
(0.60)</td><td>0.86
(0.68)
.831</td><td>0.54
(0.80)
.448</td><td>0.39
(0.53)
.091</td><td>1.08
(0.81)
.071</td><td colspan="2">1.51</td></tr>
<tr><td>Window Stool (Vacuum)</td><td>113
(60)</td><td>38.1
(0.39)</td><td>1.84
(0.50)
.231</td><td>2.51
(0.57)
.111</td><td>0.67
(0.43)
.366</td><td>0.93
(0.75)
.130</td><td colspan="2">1.79</td></tr>
<tr><td>Floor (Wipe)[2]</td><td>65
(32)</td><td></td><td></td><td>0.93
(0.34)
0.833</td><td></td><td colspan="2">0.71
(0.44)
.008</td><td>0.56</td></tr>
<tr><td>Floor (Vacuum)</td><td>233
(105)</td><td>16.2
(0.29)</td><td>1.76
(0.35)
.105</td><td>2.02
(0.36)
.053</td><td>0.56
(0.33)
.087</td><td>0.00</td><td>1.27
(0.53)
.000</td><td>0.93</td></tr>
<tr><td>Entryway (Interior Vacuum)</td><td>90
(34)</td><td>191
(0.31)</td><td>1.05
(0.38)
.902</td><td>1.15
(0.44)
.754</td><td>1.63
(0.41)
.244</td><td>0.00</td><td colspan="2">1.48</td></tr>
<tr><td>Entryway (Exterior Vacuum)</td><td>97
(46)</td><td>220
(0.37)</td><td>2.24
(0.44)
.071</td><td>1.09
(0.50)
.869</td><td></td><td>0.91
(0.69)
.076</td><td colspan="2">1.47</td></tr>
</table>

[1] Top value is multiplicative estimate, middle value is logarithmic standard error of estimate, and bottom value is observed significance level.
[2] Floor wipe samples were only collected in abated units; the geometric mean in abated units was 11.3 after controlling for significant factors.

* Significant at 5% level.

Table 4-5. Estimates[1] of Effects of Primary Abatement Factors on Lead Concentration; Controlling for Significant Covariates

(1)	(2)	(3)	(4)	(5)	(6)	Standard Deviation Estimates		
						(7)	(8)	(9)
Sample Type	No. of Samples/ Denominator Degrees of Freedom	Geometric Mean in Unabated Units After Controlling for Effects of Significant Factors	Ratio of Levels in Abated Rooms of Abated Units to those in Unabated Units	Ratio of Levels in E/E Units to those in Removal Units	Ratio of Levels in Unabated Rooms of Abated Units to those in Abated Rooms of Abated Units	Unit-to-Unit Log Standard Deviation	Room-to-Room Log Standard Deviation	Residual Log Standard Deviation
Air Duct (Vacuum)	86 (35)	332 (0.19)	1.59* (0.23) .049	2.01* (0.24) .006	0.79 (0.23) .301	0.00	0.79	
Window Channel (Vacuum)	83 (26)	851 (0.44)	0.98 (0.51) .970	1.46 (0.59) .529	0.61 (0.40) .217	0.80 (0.60) .074	1.12	
Window Stool (Vacuum)	113 (60)	416 (0.30)	1.70 (0.39) .176	1.77 (0.44) .199	0.69 (0.31) .251	0.80 (0.57) .054	1.30	
Floor (Vacuum)	233 (105)	137 (0.18)	1.03 (0.22) .888	1.30 (0.23) .258	0.87 (0.22) .534	0.00	0.71 (0.35) .000	0.77
Entryway (Interior Vacuum)	90 (34)	183 (0.22)	0.85 (0.27) .561	0.95 (0.31) .876	1.28 (0.26) .341	0.49 (0.41) .154	0.84	
Entryway (Exterior Vacuum)	97 (46)	184 (0.22)	1.19 (0.26) .509	1.01 (0.29) .976		0.52 (0.41) .097	0.89	
Entryway (Soil)	109 (12)	126 (0.18)	1.48 (0.21) .087	1.26 (0.24) .365		0.37 (0.35) .284	0.71 (0.38) .001	0.40

(1)	(2)	(3)	(4)	(5)	(6)	Standard Deviation Estimates		
Foundation (Soil)	88 (14)	86 (.14)	1.82* (0.20) .009	0.81 (0.28) .452		0.12 (0.23) .772	.44 (0.26) .004	0.28
Boundary (Soil)	120 (20)	86 (0.13)	1.63* (0.15) .004	1.27 (0.18) .205		0.37 (0.24) .021	0.44 (0.22) .000	0.21

[1] Top value is multiplicative estimate, middle value is logarithmic standard error of estimate, and bottom value is observed significance level.
* Significant at 5% level.

Table 4-6. Estimates[1] of Effects of Primary Abatement Factors on Dust Loading; Controlling for Significant Covariates

(1)	(2)	(3)	(4)	(5)	(6)	Standard Deviation Estimates		
						(7)	(8)	(9)
Sample Type	No. of Samples/ Denominator Degrees of Freedom	Geometric Mean in Unabated Units After Controlling for Effects of Significant Factors	Ratio of Levels in Abated Rooms of Abated Units to those in Unabated Units	Ratio of Levels in E/E Units to those in Removal Units	Ratio of Levels in Unabated Rooms of Abated Units to those in Abated Rooms of Abated Units	Unit-to-Unit Log Standard Deviation	Room-to-Room Log Standard Deviation	Residual Log Standard Deviation
Air Duct (Vacuum)	86 (35)	202 (.48)	3.11 (.57) .053	1.80 (0.63) .356	0.91 (0.34) .777	1.45 (0.79) .001	1.00	
Window Channel (Vacuum)	83 (26)	1857 (0.46)	0.88 (0.52) .814	0.37 (0.61) .116	0.65 (0.38) .261	0.94 (0.70) .075	1.06	
Window Stool (Vacuum)	113 (60)	92 (0.21)	1.09 (0.28) .759	1.42 (0.30) .265	0.96 (0.26) .876	0.38 (0.42) .398	1.08	
Floor (Vacuum)	233 (105)	118 (0.24)	1.65 (0.29) .089	1.55 (0.31) .165	0.65 (0.25) .088	0.44 (0.43) .301	0.84 (0.45) .000	0.85
Entryway (Interior Vacuum)	90 (34)	1054 (0.22)	1.19 (0.28) .539	1.24 (0.31) .492	1.31 (0.29) .364	0.00	1.06	
Entryway (Exterior Vacuum)	97 (46)	1152 (0.25)	1.95* (0.30) .029	1.07 (0.33) .836		0.40 (0.50) .524	1.19	

[1] Top value is multiplicative estimate, middle value is logarithmic standard error of estimate, and bottom value is observed significance level.
* Significant at 5% level.

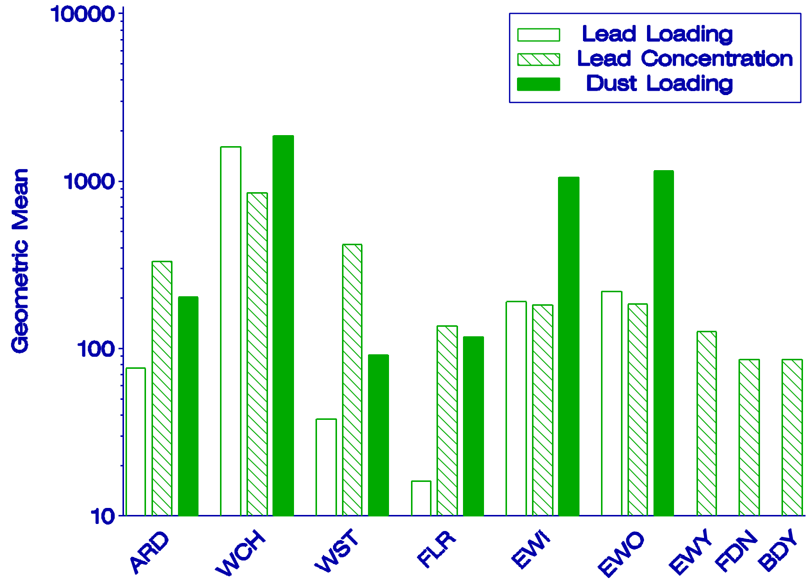


Figure 4-1. Geometric mean lead loading, (µg/ft^2), lead concentration (µg/g), and dust loading (mg/ft^2) in unabated units after controlling for effects of significant factors.

dust loading. Some interesting points to note regarding these geometric means are as follows:

- The highest lead loadings were observed in the window channels, and the lowest were observed on floors.
- There was very little distinction between interior and exterior entryway dust samples in unabated houses, both for lead concentration and dust loading.
- Entryway dust loadings were higher than those in the air ducts.
- Entryway soil lead concentrations were higher than boundary or foundation concentrations in unabated houses.

One thing to keep in mind when observing dust levels on floors (and interior entryways) is that substrate was an important differentiating factor. The geometric means presented are based on the observed aggregate average across substrates. The ratios of average levels on different substrates to this geometric mean are described in Section 4.2.4. For instance, dust loading and therefore, lead loading, were much higher than average on carpet.

The fourth column in Tables 4-4, 4-5, and 4-6 displays the estimated ratio of levels in abated rooms of abated houses to levels in unabated houses. The fifth column contains the estimated impact of abatement method, which should be interpreted as the ratio of levels in abated rooms of typical E/E houses to levels in abated rooms of typical removal houses (see Section 3.2). The sixth column in these tables gives an estimate of the ratio of levels in unabated rooms of abated houses to levels in abated rooms of abated houses. The log standard error and significance level of these estimates appear beneath each estimate. The latter represents the observed significance of a test that the ratio equals 1.

The following are the statistically significant results for the estimated effects of primary abatement factors:

- Air Ducts -- Lead loadings and lead concentrations were higher in abated houses than in unabated houses. Lead loadings and lead concentrations were higher in E/E houses than removal houses.

- Soil Samples -- Lead concentrations in soil outside abated houses were consistently greater than those outside unabated houses. This was especially evident in foundation samples, followed in magnitude by boundary samples.

- Exterior entryway -- Dust loadings were higher in abated houses than in unabated houses.

There were other differences observed which were not statistically significant, but worth noting:

- Floors (Vacuum) -- Lead loadings were higher in E/E houses than in removal houses (p=.053). Lead loadings and dust loadings were higher in abated houses than in unabated houses (for lead loadings p=.105; for dust loadings p=.089). Lead loadings were lower in unabated rooms of abated houses than in abated rooms (p=.087).
- Exterior Entryway -- Lead loadings were higher in abated houses than in unabated houses (p=.071).
- Soil Samples -- Lead concentrations in entryway soil samples outside abated houses were greater than those outside unabated houses (p=.087).

The estimates from columns 4, 5, and 6 of Tables 4-4, 4-5, and 4-6 are displayed graphically in Figures 4-2, 4-3, and 4-4 for lead loading, lead concentration, and dust loading, respectively. (Figures 4-2 and 4-3 duplicate Figures 1-1 and 1-2, respectively.) Reference lines are provided on these plots at a level of one. An asterisk indicates that the effect was significant at the 5 percent level. A bar which rises above the reference line for the `Abatement' factor indicates that for this sample type levels were higher in abated houses than in unabated houses. A bar which rises above the reference line for the 'Method (E/R)' factor indicates that the levels in E/E houses were higher than those in removal houses. If the 'Unabated room' effect is greater than one, then levels in unabated rooms of abated houses were higher than in abated rooms.

The most significant difference between abated and unabated houses was observed in the air ducts for lead loadings and lead concentrations. Perhaps more striking in these figures is the frequency with which the 'Method (E/R)' bar rises above the reference line. As mentioned above, this indication that E/E houses have higher lead levels than removal houses could simply be a reflection of a more serious initial lead problem in the E/E houses.

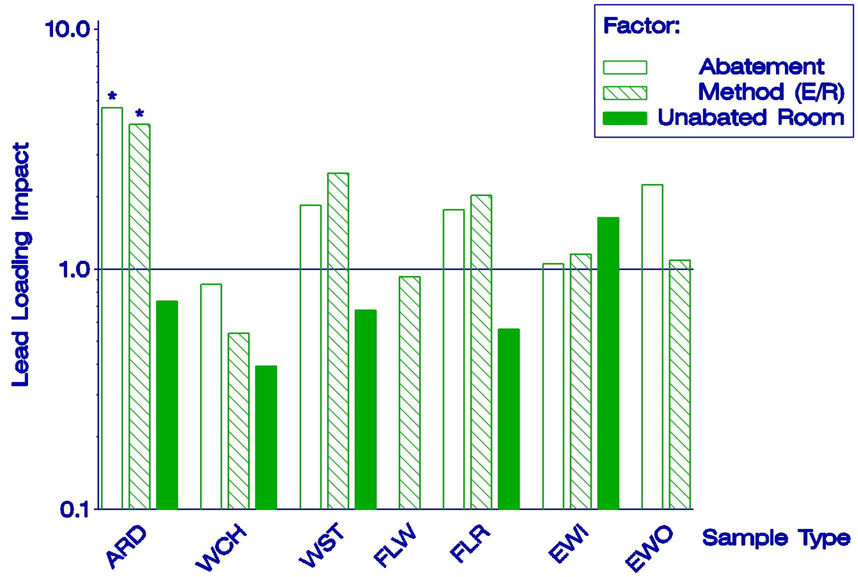
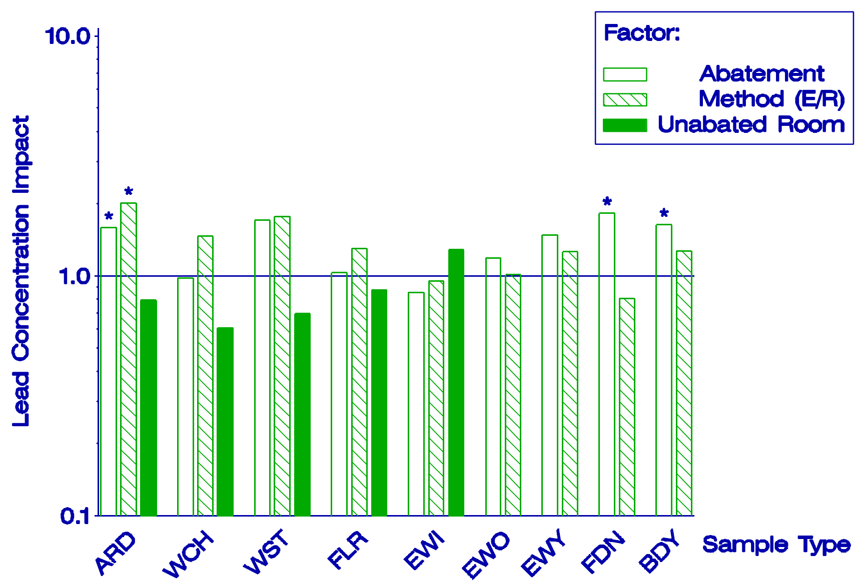


Figure 4.2 Estimated multiplicative effects of abatement from mixed model ANOVA: Lead Loading (*indicates



significance at the 5% level).

Figure 4.3 Estimated multiplicative effects of abatement from mixed model ANOVA: Lead Concentration (*indicates significance at the 5% level).

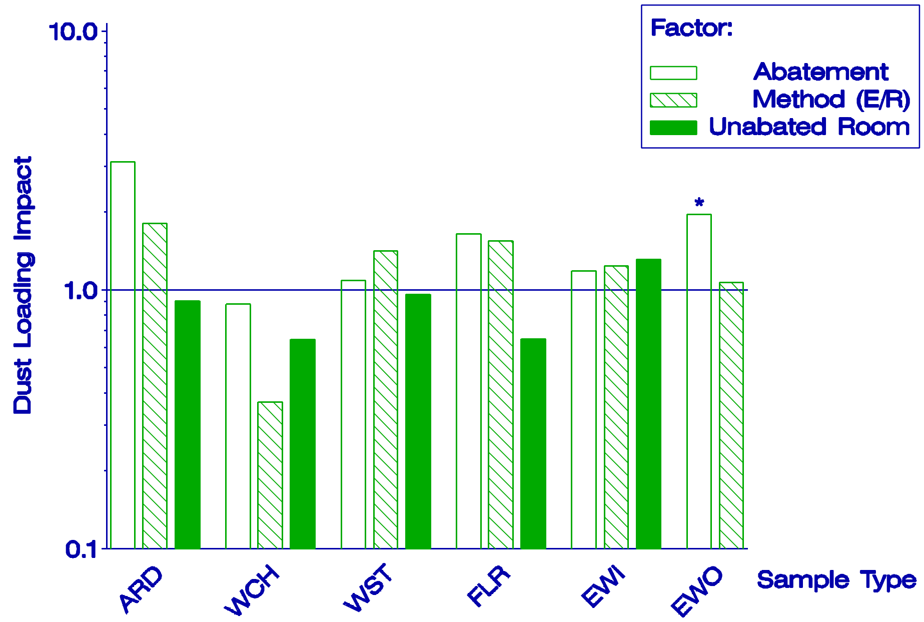


Figure 4.4 Estimated multiplicative effects of abatement from mixed model ANOVA: Dust Loading (*indicates significance at the 5% level).

Similarly, the figures portray lower levels in the unabated rooms of abated houses than in abated rooms of the same houses. This indicates that abatement performed in the rooms that needed it did not reduce lead levels to the baseline levels found in unabated rooms that did not require abatement.

In order to obtain estimates of average lead loadings, lead concentrations, or dust loadings in typical abated houses, multiply the geometric mean in column three by the ratio estimate in column four in Tables 4-4, 4-5, or 4-6, respectively. As an example, consider the estimation of the average lead concentration on floors. First, the average lead concentration on the floors of typical abated houses is obtained by multiplying the estimate of the geometric mean in unabated houses (column three of Table 4-5) by the ratio of levels in abated houses to those in unabated houses (column four of Table 4-5):

$$137 \times 1.03 = 141.1\ \mu g/g. \qquad (4\text{-}1)$$

Table 4-7. Exponents for Deriving Geometric Means in E/E and Removal Houses

Sample Type	Exponent for E/E Houses	Exponent for Removal Houses
Interior Samples	0.292	-0.708
Exterior Samples	0.215	-0.785

In order to obtain the corresponding estimates for typical E/E or typical removal houses, multiply the geometric mean for a typical abated house by the ratio estimate in column five of Table 4-4, 4-5, or 4-6, raised to the appropriate exponent in Table 4-7. For example, to obtain the estimate of average lead concentration on floors of E/E houses, multiply (4-1) by the estimate of the ratio of levels in E/E houses to those in removal houses (fifth column of Table 4-5) raised to the exponent for E/E houses in Table 4-7:

$$141.1\ (\mu g/g) \times 1.30^{0.292} = 152.3\ (\mu g/g).$$

To obtain the estimate for removal houses, multiply (4-1) by the estimate of the ratio of levels in E/E houses to those in removal houses (fifth column of Table 4-5) raised to the exponent for removal houses in Table 4-7:

$$141.1\ (\mu g/g) \times 1.30^{-0.708} = 117.2\ (\mu g/g).$$

Analysis of Random Effects

The last three columns of Tables 4-4 through 4-6 provide estimates of the house-level, room/side-level (side refers to side of house in the case of soil samples), and residual error-level variance components, after correcting for modeled factors. Only in the case of vacuum floor samples and soil samples were the room/side-level variance components estimable. The values presented are given as standard deviations of the log-transformed responses. Except in the case of residual standard deviation, each estimate is followed by its standard error estimate and a test of significance that the log standard deviation equals zero. Figures 4-5, 4-6, and 4-7 display the estimates of these variance components. The variances are summed and stacked in these plots providing an estimate of overall uncontrolled variance in the measures. Interesting points to note regarding the variance estimates are the following:

- There was much more variability in lead concentration observed in window channel and window stool samples than any other sample type.

- Among soil sample types, random variability was greatest at the entryway and smallest at the foundation.

- The greatest relative variability in dust lead loadings was observed for air ducts, window channels, and window stools.

- The greatest relative variability in dust loading was observed for air ducts.

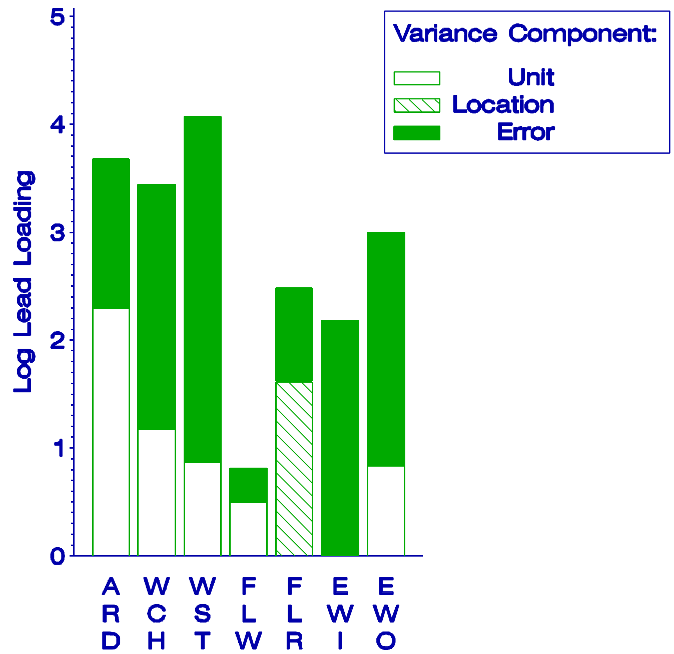


Figure 4-5. Variance component estimates from mixed model ANOVA: Lead Loading.

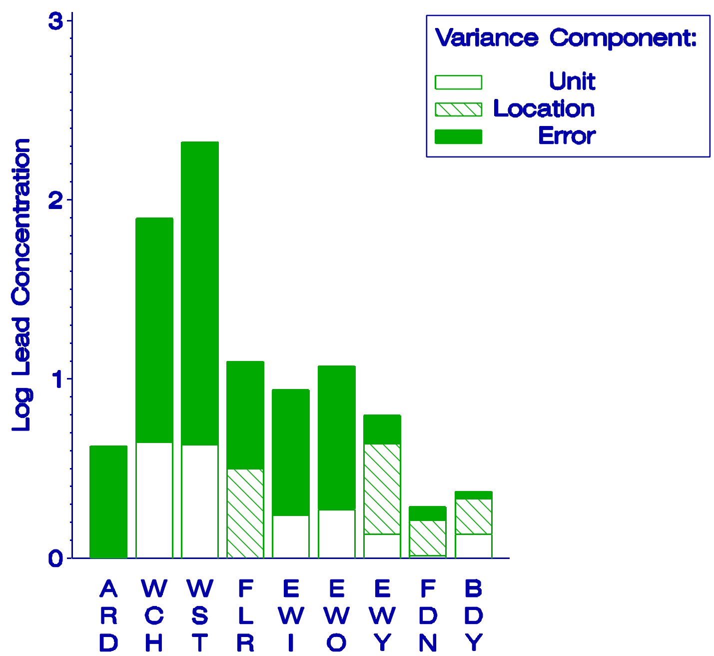


Figure 4-6. Variance component estimates from mixed model ANOVA: Lead Concentration.

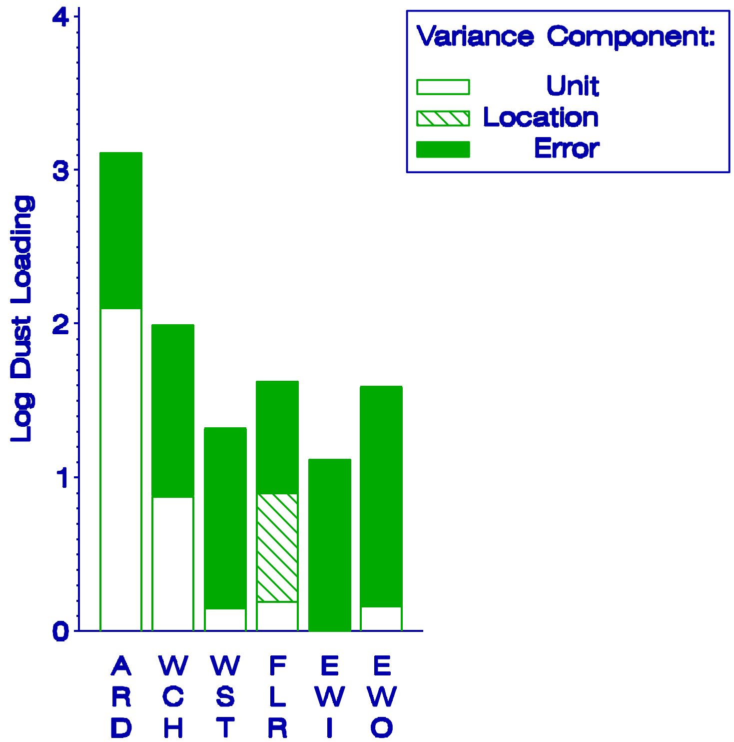


Figure 4-7. Variance component estimates from mixed model ANOVA: Dust Loading.

One of the considerations in interpreting these variance components is that different models were fit to different sample types. Therefore, for some sample types, more factors are controlled. For example, more factors were controlled in the case of foundation soil samples than any of the other soil samples; in particular, this was the only sample type for which XRF measures from the HUD Demonstration were included.

Effects of Secondary Abatement Factors

Table 4-8 displays estimates of the effects of secondary abatement factors found to be significantly associated with lead levels for at least one of the sample types. Each factor is followed by a description of the nominal level of the factor. The geometric means displayed in Table 4-4 through 4-6 should be interpreted as though levels of these factors were fixed at the nominal levels. The third column of Table 4-8 describes the deviation from nominal with which the multiplicative effects in the last three columns are associated. The fourth column of Table 4-8 displays the sample types for which each of these factors was significant. The last three columns display the estimated multiplicative effects of the stated deviations of these factors on lead loading, lead concentration, and dust loading. Two asterisks are placed in the multiplicative effect box for each response where the association was significant at the 5 percent level. As explained in Section 3, a factor was included in the model if it was found to be significant at the 10 percent level for either lead loading or lead concentration. However, in Table 4-8, all factors indicated as significant were actually significant at the 5% level - except in three cases, which are noted by single asterisks.

For example, the estimated geometric mean lead concentration on window channels in unabated houses (Table 4-5) was 851. The amount of interior abatement performed and the specific removal method used were found to be significant for this component. To estimate the average concentration in abated houses with twice as much abatement - holding all other factors at the nominal level -

Table 4-8. Multiplicative Effects of Secondary Abatement Factors

(1) Factor	(2) Nominal	(3) Deviation	(4) Sample Type	Multiplicative Effect (5) Lead Loading	(6) Lead Concentration	(7) Dust Loading
Total Interior Square Feet Abated	282 for Typical E/E 61 for Typical Removal 180 for Typical Abated	Double square feet abated	Floor (Vacuum)	(E) 0.97 (R) 1.17*	(E) 1.03 (R) 1.16**	(E) 0.95 (R) 1.03
			Window Channel	1.29	1.34**	0.96
			Window Stool	1.46**	1.22	1.19
Total Exterior Square Feet Abated	628 for Typical E/E 260 for Typical Removal 519 for Typical Abated	Double square feet abated	Window Channel	0.49**	0.59**	0.83
			Foundation	NA	0.66**	NA
Room Removal Method • Chemical Stripping • Removal/Replace • Heat Gun • Removal	 15% 15% 30% 40%	*** +10% +10% +10% +10%	Window Channel	** 0.74 1.10 1.09 1.00	** 0.95 1.11 1.27 1.00	* 0.77 0.99 0.86 1.00
Abatement Contractor • A (3 units) • B (15 units) • C (13 units) • D (4 units)	NA	NA	Air Ducts	 0.55 1.01 0.78 3.35	** 2.34 0.77 0.91 1.81	 0.24 1.36 0.83 1.87
Phase of Abatement • 1 (13 units) • 2 (13 units) • 3 (9 units)	NA	NA	Floor (wipe)	* 1.57 0.65 1.01	NA	NA

Last XRF measure at sample location during HUD demonstration	0.10 for control 0.44 for abated	Double XRF reading	Foundation	NA	1.16**	NA

* Significant at the 10% level but not at 5% level. For groups of factors, indicates that the group as a whole is significantly related.

** Significant at the 5% level.

*** Estimates reflect expected change due to 10% increase in specified removal method. [Sum must equal 100%.]

**** For abatement contractor and phase of abatement effects, estimates reflect difference from observed overall average for use of specific contractor or abatement performed in specific phase, e.g., lead concentrations in houses abated by contractor B were 77 percent of the (geometric) average across contractors.

multiply the geometric mean from Table 4-5 (851 μg/g) by the ratio of abated houses to unabated houses (0.98, from column four of Table 4-5) and by the estimated effect of doubling square footage abated, 1.34, displayed in Table 4-8. That is

$$851 \times 0.98 \times 1.34 = 1117.5\ \mu g/g. \tag{4-2}$$

One must note that this is an estimate for the "typical" abated house, which has (from the second column of Table 4-8) 180 square feet of interior abatement, and from Table 3-2, 67 percent of this abatement performed by E/E methods. To adjust this estimate for homes abated primarily by removal methods where 122 square feet were abated (61 times 2), simply multiply estimate (4-2) by the adjustment required for window channels in removal houses:

$$1117.5\ (\mu g/g) \times 1.46^{-0.078} = 855\ \mu g/g\ .$$

On floors, the impact of increased abatement was significantly different for houses abated by E/E methods compared to houses abated by removal methods. In particular, at E/E houses, there was little effect observed for increased abatement. But at houses abated by removal methods, greater lead concentrations were found in the dust in houses where more abatement was performed. Thus, an estimate of average lead concentration on the floors of houses abated primarily by removal methods with twice as much abatement as was typical for removal houses is a follows:

$$\underbrace{137 \times 1.03}_{\text{average level in typical removal house}} \times \underbrace{1.30^{-0.708} \times 1.16}_{\text{effect of twice the average abatement for removal houses}} = 136\ \mu g/g\ .$$

Estimating the effect of deviating from the nominal levels of abatement by specific removal methods is more complicated;

each of the deviations needs to be accounted for. For example, the multiplicative adjustment to lead concentration necessary to describe levels in an abated room of an abated house in which 50 percent of the removal was done with a heat gun and 50 percent was done by chemical stripping, would be

$$(0.95)^{3.5}\ (1.11)^{-1.5}\ (1.27)^{2}\ (1.00)^{-4} = 1.15.$$

The numbers in parenthesis come from the sixth column of Table 4-8, and relate to the interior removal abatement method: 0.95 for chemical stripping, 1.11 for remove/replacement, 1.27 for heat gun, 1.00 for removal. The proportion abated by removal is implicitly defined by specifying the proportion abated by the other three methods. Therefore, removal does not have to be accounted for explicitly; it is only presented here for clarity. The exponents in the equation describe the percentage of each method used as it deviates from the nominal level. The exponent 3.5 represents three and one half "deviations" from the nominal percentage of 15%, the exponent -1.5 represents negative one and one half deviations from the nominal percentage of 15%, the exponent 2 represents two deviations from the nominal percentage of 30%, and the exponent -4 represents negative four deviations from the nominal percentage of 40%.

By the method of variable screening used, every factor represented in Table 4-8 is significant for either lead loading or lead concentration. It is interesting to note that almost every significant factor had a significant impact on lead concentrations. The exceptions were phase of abatement for floor wipe samples (for which there was no concentration measured) and total interior square feet abated for window stools. Appendix C contains the detailed model fitting results listed by sample type and response.

Some important items to note regarding the effects of these secondary abatement factors are:

- Houses with large amounts of interior abatement were associated with higher lead levels on floors (see discussion below), window channels and window stools.

- Houses with large amounts of exterior abatement were found to have lower lead loadings and concentrations in window channels, and lower lead concentrations in foundation soil samples.

- Higher lead concentrations in foundation soil samples were found at houses with higher XRF/AAS readings during the HUD Demonstration.

4.2.2 Analyses of Abatement and Random Effects by Sample Type

The previous section summarized modeling results across all sample types collected. This section breaks down these modeling results into more detailed discussions for each sample type separately. In this discussion of each sample type, an effect is described as "statistically significant" if its observed significance level, or p-value, is less than 5 percent (or 0.0500). Effects with observed significance level between 5 and 10 percent are noted below, with their associated p-value, but are not declared statistically significant.

Dust Samples

This subsection presents modeling results for all locations at which dust samples were collected.

Air Ducts. There were higher levels of lead in air ducts of abated houses than in unabated houses, and levels were higher in houses abated by the E/E methods than by the removal methods. Lead loadings were almost five times higher and lead concentrations were 60 percent higher in abated homes. Lead loadings in typical E/E houses were four times higher than in typical removal houses. Concentrations were only twice as high. The above results were all statistically significant, however unabated rooms in the abated houses did not have lead levels significantly different than those in abated rooms of the same houses.

House-to-house variation was highest in air ducts for lead loadings and dust loadings. However, house-to-house variation in air duct lead concentration was negligible. This indicates that for air ducts, most house-to-house variation in air duct lead loading is due to the differences in dust levels in these houses.

A significant association was found between the observed lead concentrations in air ducts and the contractors used to perform the abatements in the HUD Demonstration.

Window Channels. There was no significant difference in lead levels observed in the window channels of abated and unabated houses. Nor were there differences between lead levels in houses abated by E/E and removal methods. However, lead loadings in unabated rooms of abated houses were about 40% as high as in the abated rooms of these houses.

There were significant differences in lead concentration and lead loading associated with use of the specific removal methods at the room level. Of the four different methods, heat gun use was associated with the highest concentrations. Total square feet abated - both interior and exterior were also statistically significant covariates. Doubling exterior square feet abated was associated with a reduction of lead loadings by half, and lead concentrations by 40 percent. Doubling interior square feet abated was associated with a 34 percent increase in lead concentration.

Houses abated by E/E methods typically had much more abatement performed than the houses abated primarily by removal methods. The estimates provided are adjusted for this potential confounding factor. A typical interior removal house is defined as having 61 total square feet abated indoors; for a typical interior E/E house, 282 square feet of interior abatement is assumed. These numbers are based on a regression of (log) square feet abated on the percent abated by E/E methods.

Window channels and window stools were associated with the greatest total variation in lead levels. The variation was particularly notable for lead concentrations (see Figures 4-5 and 4-6).

Window Stools. Neither differences between lead loadings nor lead concentrations in abated and unabated houses was statistically significant. Although geometric mean lead loadings were about twice as high on window stools of abated houses than they were in unabated houses, there was also large variability observed in the results. Lead loadings were 2.5 times as high on window stools in the average E/E house as in the average removal house. Lead concentrations were about 1.8 times as high in these houses. These results were not significant at the 5% level. There were no significant differences in dust loadings between these houses. Although lead levels were about a third lower in unabated rooms of abated houses, the differences were not statistically significant.

Floor (Wipe). Abatement method was the only abatement effect which was estimated for floor lead loadings from wipe samples. Although levels were slightly lower in E/E houses, no significant differences were found.

Random house-to-house variation was statistically significant for this sample type, but it was moderate in magnitude. The estimated residual log standard deviation was smallest for this sample type, but this requires some explanation. By design, the floor wipe samples were taken to compare with the floor vacuum samples (see Section 6). Two side-by-side samples were taken per abated house. Thus, the residual log standard deviation is really a measure of side-by-side sample variability. This is in contrast with the other dust sample types for which the two samples per house were often taken from different rooms.

The houses abated in the HUD Demonstration in Denver were abated in three different phases according to the magnitude of abatement required. The worst houses were abated first. Table 4-8 indicates higher lead levels were found in homes abated in the first phase than in the second phase, with levels in the third phase about average.

Floor (Vacuum Samples). About twice as many floor (vacuum) samples were taken as for any other sample type in the study. No statistically significant contrasts were observed for the primary abatement effects, but there were higher levels of dust on the floors of abated houses (p=.089) contributing to higher, but not significantly higher (p=.105) lead loadings in these houses. Lead loadings in houses abated by E/E methods were twice as high as in removal houses (p=0.53), due to a combination of slightly higher lead concentrations and slightly higher dust loadings in these houses.

There was a significant relationship observed between the total square feet abated indoors and lead concentration (see Table 4-8). But this relationship depended on whether the abatement was primarily E/E, or primarily removal. Houses where a large amount of abatement was performed primarily by removal methods were associated with significantly higher lead levels. Doubling square feet abated indoors was associated with about 16% higher concentrations and 17% higher lead loadings. In E/E houses this difference was only about 3% for concentration and negative 3% for loading. These differences were not statistically significant.

There were negligible random house-to-house differences in both lead loadings and lead concentrations for floor samples. Although not significant, there were differences present in dust loadings. There were significant room-to-room differences within houses for lead loadings, lead concentrations, and dust loadings. It is interesting to note that in Figure 4-5, the room-to-room variance component alone for vacuum floor samples is greater than the estimated total variance for the corresponding wipe samples. (In the figure, the room-to-room variance component is represented by "Location"). Another practical note illustrated by this figure is that the residual log standard deviation estimate (the within-room component) for vacuum floor samples is larger than that for wipe floor samples. However, in some cases, repeated vacuum floor samples taken within the same room were taken from different locations within the room, as opposed to side-by-side as were the wipe floor samples. Thus, this standard deviation includes within-room variation, whereas, the floor wipe residual standard deviation does not. A complete discussion of the wipe and vacuum sample comparisons is presented in Section 6.

Interior Entryway. There was no significant difference observed in lead levels among the three categories of homes. Nor was there a significant unabated room effect in abated homes.

Perhaps the most interesting thing to note about these samples is the corrected geometric mean lead loading. The estimated lead loading for interior entryways in unabated houses is 12 times higher than that for regular floor (vacuum) samples. This difference is due to only a 33% difference in lead concentration, but a nine-fold difference in dust loading.

Although it was not statistically significant, there was random house-to-house variation in lead concentration, but not in lead loading or dust loading. Residual log standard deviation was relatively large for lead loading. The residual variation primarily represents differences between entryways within the same house.

Exterior Entryway (Dust). Although not statistically significant, there were differences in lead loading in the dust outside the entryways sampled. Lead loadings in abated houses were more than twice as high ($p=.07$) as outside unabated houses. These differences were due to significantly higher dust levels at the abated houses ($p = .03$), not to higher concentrations of lead in this dust. There was no difference observed in levels abated by different methods.

There was random house-to-house variation ($p=.076$) in lead loading at exterior entryways. This was due to random variations in lead concentration ($p=.097$), not to dust loading variations. Residual log standard deviation was very large for lead loading (as for the interior entryways).

It is interesting to note that the average lead concentrations for interior and exterior entryway samples at unabated houses were almost identical. Differences between abated houses and unabated houses were only observed on the exterior.

Soil Samples

The strongest relationships between lead concentrations and abatement were seen in soil samples. Lead concentrations were higher outside abated houses than outside unabated houses. Controlling for all covariates, lead concentrations outside unabated houses were highest at the entryway. There was significant side-to-side variation for each of the measures and significant house-to-house variation for boundary samples. The greatest total variance was observed for entryway samples. Side-by-side variation was largest at the entryways.

Entryway (Soil). Although not statistically significant, the soil outside entryways of abated houses had average lead concentration about 50% higher than outside unabated houses ($p=.087$). Average levels at unabated houses were estimated at 126 μg/g. Random house-to-house variability in entryway soil lead concentrations was not statistically significant, but there were significant random differences between levels observed at different entryways to the same houses.

Boundary Soil. Soil concentrations at the boundaries of unabated houses were 86 μg/g on average. At abated houses, concentrations were more than 60% higher. This was very significant. Differences observed between levels at houses abated by different methods were not significant.

There was significant random house-to-house variation, and significant side-to-side variation.

Foundation Soil. In soil, the greatest difference between lead concentrations in abated houses and unabated houses was seen at the foundation. Lead concentrations were 82 percent higher in the soil near foundations of abated houses than at unabated houses. This difference was statistically greater than the corresponding difference at the boundary, supporting claims that contrasts may at least in part be due to the presence of lead-based paint at the abated houses.

Differences observed between levels in houses abated by different methods were not significant. Also, lead concentrations were significantly lower in the foundation soil of houses with more than average abatement performed on the exterior. Houses where twice as much abatement was performed outside were found to have 34% lower lead concentrations.

House-to-house differences were not significant, but side-to-side variation was significant. There was a strong correlation between the foundation soil lead concentrations observed in the CAP Study and the XRF/AAS measures taken during the HUD Demonstration. This relationship is displayed in Figure 4-8. In this figure, lines of best fit are drawn separately for control and abated houses. Although lead concentrations are higher on average in abated houses than in unabated houses, there is evidently a similar relationship between lead concentration and XRF measures for both groups of houses.

4.2.3 <u>Analysis of Non-Abatement Factors</u>

Table 4-9 displays the effects of non-abatement factors found to be significantly associated with lead levels. These included substrate, questionnaire responses, age of the house, etc. The format of the table is similar to Table 4-8 with an initial column added to distinguish between classes of related factors. These classes include substrate, cleanliness, occupation, activities, ownership, and sampling deviations.

None of these factors was found to be significant for more than three sample types. For every sample type, lead loading or

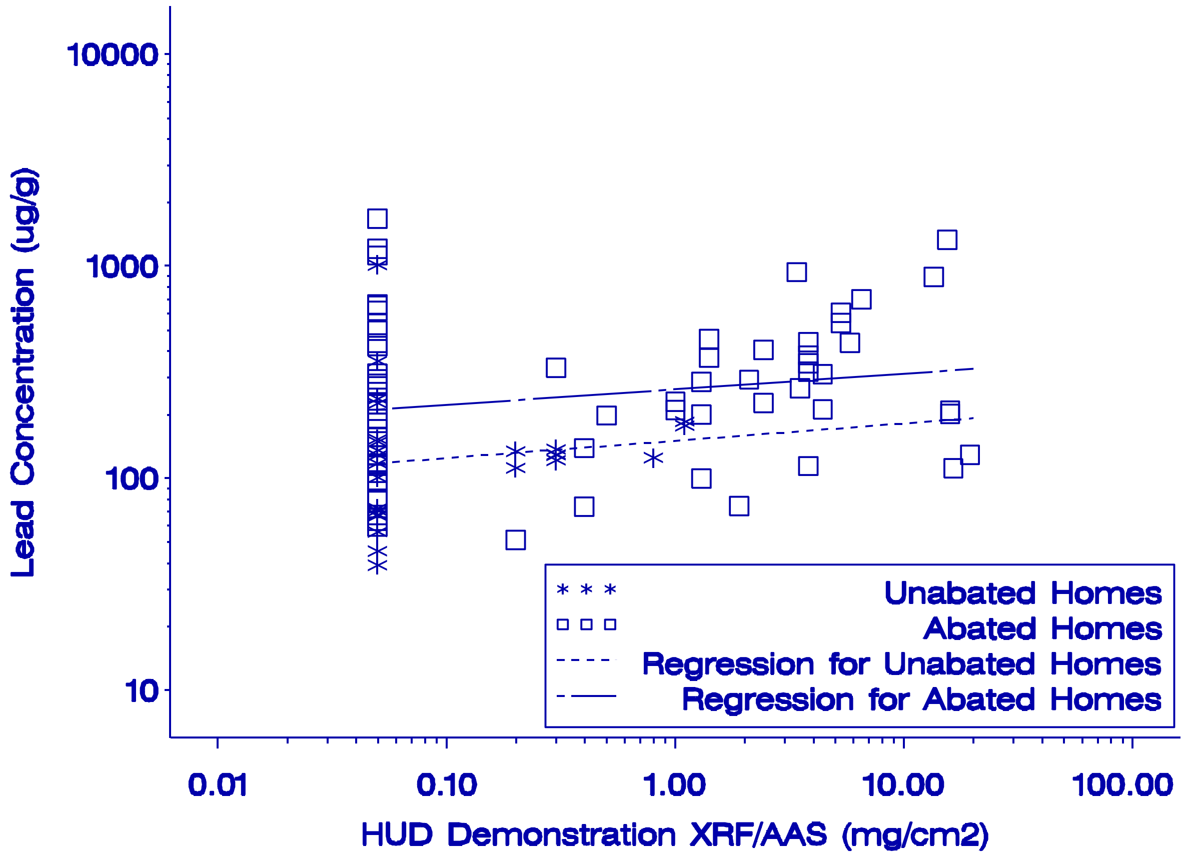


Figure 4-8. **Foundation soil lead concentration vs. HUD Demonstration XRF/AAS levels.**

lead concentration was observed to be significantly associated with at least one of these factors at the 10 percent significance level.

The substrate from which samples were collected was a significant factor for window channels, floors, and interior entryways. This is displayed in Figure 4-9 for floors with a box and whisker plot. (The same format is used in this plot as was used in Section 2 plots.) The corrected geometric means presented in Tables 4-4 through 4-6 are to be interpreted as the mean across substrate weighted by their observed relative frequency in the study. Table 4-9 indicates the distribution of the substrates encountered in this study. For regular floor samples, carpet and linoleum were most prevalent. For interior entryways, carpet was most often observed. Wood was the most prevalent substrate in window channels. Table 4-9 presents the ratio of levels observed for each substrate relative to the average.

In general, on the floors (including interior entryways), carpet had higher dust loadings than any of the other sample types. (Although the dust loadings were highest on concrete, only four samples were collected on that substrate.) Lead concentrations were typically highest on wood (excluding concrete) for all of the sample types where substrate was found to be significant. Lead loadings were higher on wood than on carpet for regular floor samples, but the opposite was true at the entryways. The condition of the substrate was also significant, with damaged, peeling, and chalking substrates noted for higher lead concentrations.

Sampling deviations were also significant factors. On some air ducts, the cover was not removable and so a sample was taken from the cover. These samples had one quarter of the dust loading and lower lead concentrations as compared with regular samples taken from inside the air ducts. For some window stool and some window channel samples a small nozzle was used on the end of the vacuum sampler. Lead concentrations and dust loadings

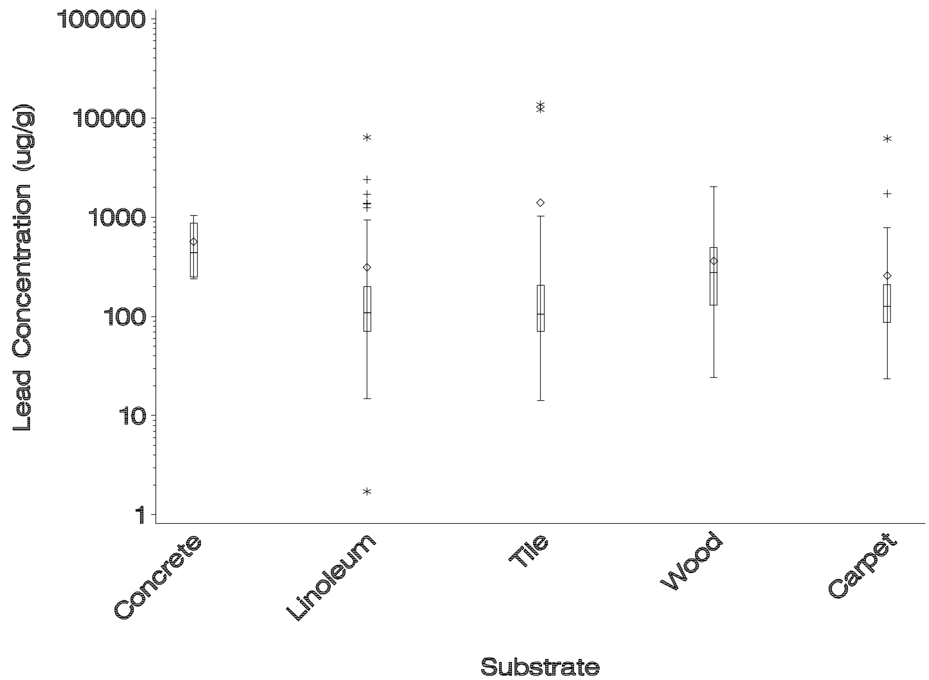


Figure 4-9. Floor dust lead concentration vs. substrate.

Table 4-9. Multiplicative Effects of Non-Abatement Factors

Type of Explanatory Variable	Factor	Nominal[1,2]	Deviation[2]	Sample Type	Multiplicative Effect: Lead Loading	Multiplicative Effect: Lead Concentration	Multiplicative Effect: Dust Loading
Substrate	Substrate Type	Observed average across substrates		Window Channel	*	*	*
			Wood (44)		1.94	1.67	1.14
			Concrete (1)		0.93	6.45	0.15
			Metal (33)		0.62	0.55	1.14
			Plastic (5)		0.07	0.37	0.19
					*	NA	NA
			Concrete(1)	Floor (Wipe)	24.19		
			Linoleum(38)		0.84		
			Tile(8)		0.66		
			Wood(18)		1.44		
				Floor (Vacuum)	*	*	*
			Carpet (84)		2.22	0.79	2.76
			Concrete (4)		27.52	3.44	8.96
			Linoleum (85)		0.31	0.87	0.35
			Tile (20)		0.27	0.94	0.29
			Wood (40)		3.22	2.04	1.63
				Entryway (Interior)	*		*
			Carpet (47)		2.79	0.99	2.89
			Linoleum (26)		0.43	0.93	0.43
			Plastic (2)		0.02	0.76	0.02
			Tile (7)		0.08	1.07	0.07
			Wood (8)		0.97	1.33	0.77
	Substrate Condition	Good (82)		Air Duct	*	*	*
			Damaged (1)		41	1.5	28
			Peeling (3)		28	6.7	2.5

[1] Weighted by observed relative frequencies.
[2] Number in parentheses represents the number of samples collected in this manner.
* Significant at the 10% level. For group of factors, * indicates that the group as a whole is significant.

Table 4-9. (Continued)

Type of Explanatory Variable	Factor	Nominal[1,2]	Deviation[2]	Sample Type	Multiplicative Effect		
					Lead Loading	Lead Concentration	Dust Loading
		Good (48)		Window Channel		*	
			Chalking (2)		1.78	3.16	0.56
			Peeling (33)		3.06	2.71	1.17

[1] Weighted by observed relative frequencies.
[2] Number in parentheses represents the number of samples collected in this manner.
* Significant at the 10% level. For group of factors, * indicates that the group as a whole is significant.

Table 4-9. (Continued)

Type of Explanatory Variable	Factor	Nominal[1,2]	Deviation[2]	Sample Type	Multiplicative Effect		
					Lead Loading	Lead Concentration	Dust Loading
Cleanliness	Frequency of vacuuming uncarpeted floors	12 times/mo	6 additional times/mo	Floor (Vacuum)	1.02	1.03*	1.00
				Entryway (Interior)	1.06*	1.06*	0.99
				Entryway (Exterior)	1.00	1.05*	0.96*
	Frequency of wet mopping uncarpeted floors	12 times/mo	6 additional times/mo	Air Duct	0.97	0.98*	0.98
	Frequency of window sill dusting	1 time/mo	1 additional time/mo	Air Duct	0.99	1.03*	0.96
Occupation	Wearing home work clothes from an occupation with potential lead contamination	No	Yes	Window Stool	2.96*	1.45	2.01*
				Entryway (Soil)	NA	0.66*	NA
	Resident employed in welding occupation	No	Yes	Floor (Vacuum)	9.08*	3.72*	2.49*
				Foundation	NA	1.82*	NA
	Resident employed in salvage occupation	No	Yes	Boundary	NA	1.13*	NA

[1] Weighted by observed relative frequencies.
[2] Number in parentheses represents the number of samples collected in this manner.
* Significant at the 10% level. For group of factors, * indicates that the group as a whole is significant.

Table 4-9. (Continued)

Type of Explanatory Variable	Factor	Nominal[1,2]	Deviation[2]	Sample Type	Multiplicative Effect		
					Lead Loading	Lead Concentration	Dust Loading
	Resident employed in paint removal occupation	No	Yes	Boundary	NA	0.40*	NA

[1] Weighted by observed relative frequencies.
[2] Number in parentheses represents the number of samples collected in this manner.
* Significant at the 10% level. For group of factors, * indicates that the group as a whole is significant.

Table 4-9. (Continued)

Type of Explanatory Variable	Factor	Nominal[1,2]	Deviation[2]	Sample Type	Multiplicative Effect		
					Lead Loading	Lead Concentration	Dust Loading
Activities	Frequency of removing paint at home	Never in last 6 months	1 additional time per 6 months	Entryway (Interior)	1.06	1.10*	0.97
				Foundation	NA	0.85*	NA
	Frequency of pipe or electrical component soldering	Never in last 6 months	1 additional time per 6 months	Boundary	NA	1.32*	NA
Ownership	Number of children (7-17)	0	1 additional child	Entryway (Interior)	0.64*	0.81*	0.78*
	Ownership of home	Owner	Renter	Foundation	NA	0.32*	NA
				Floor (Wipe)	0.58*	N/A	N/A
	Number of months at residence	18	1 month longer	Foundation	NA	0.94*	NA
	Year house was built	1943 for unabated 1926 for abated	10 years newer	Entryway (Soil)	NA	0.90*	NA
				Foundation	NA	0.77*	NA
				Boundary	NA	0.83*	NA
	Number of Pets	0	1 additional pet	Floor (Vacuum)	1.02	0.82*	1.27*

[1] Weighted by observed relative frequencies.
[2] Number in parentheses represents the number of samples collected in this manner.
* Significant at the 10% level. For group of factors, * indicates that the group as a whole is significant.

Table 4-9. (Continued)

Type of Explanatory Variable	Factor	Nominal[1,2]	Deviation[2]	Sample Type	Multiplicative Effect		
					Lead Loading	Lead Concentration	Dust Loading
Sampling Deviations	Sampling Location	Inside Air Duct (48)	Cover of Air Duct (38)	Air Duct	0.18*	0.78	0.26*
	Sampling Device	Large Nozzle (60)	Small nozzle (26)	Window Channel	3.47*	1.56	2.14*

[1] Weighted by observed relative frequencies.
[2] Number in parentheses represents the number of samples collected in this manner.
* Significant at the 10% level. For group of factors, * indicates that the group as a whole is significant.

were greater for these samples than for those collected with the large nozzle.

Older homes had higher soil lead concentrations than newer homes for all three soil sample types. This is demonstrated for boundary samples in Figure 4-10. Abated and unabated homes are identified in this figure with a different regression line plotted for each class of homes describing the relationship between house age and lead concentration in the soil. As was the case for XRF measures, average lead concentration is higher in the abated houses than in the unabated houses, but the relative increment due to age is similar in both groups of houses.

Houses where pipes or electronic parts were soldered within the last 6 months had 33% higher lead concentrations. Other significant factors were less intuitive. For instance, lower lead concentrations were observed in boundary soil of houses where residents are employed in a paint removal occupation. For completeness, all factors significant at the 10% level are represented, even if they do not appear to be intuitive.

Although past studies (EPA, 1995b) have documented seasonal variation in environmental-lead levels, data was collected for this study during an interval of five weeks during March and April 1992. Therefore, it was not necessary to control for seasonal variations in comparing abated to unabated houses. However, in comparing average levels observed in this study to those in other studies it might be important to compare the times of year in which sampling was performed.

Some caution needs to be applied in the interpretation of significant effects. For example, there were two houses in which the resident interviewed stated that the uncarpeted floors were vacuumed every day. In these houses, lead concentrations were significantly higher in exterior entryway samples at these houses. This relationship is portrayed in Figure 4-11. Whereas the frequency of vacuuming uncarpeted floors was found to be significantly associated with lead concentrations for these sample types for the houses in the study, when the two houses

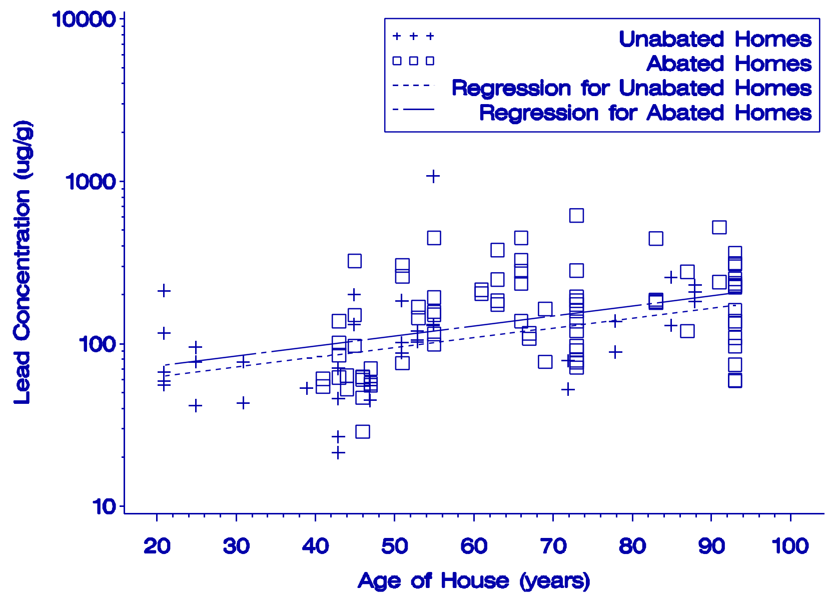


Figure 4-10. Boundary soil lead concentration vs. age of house.

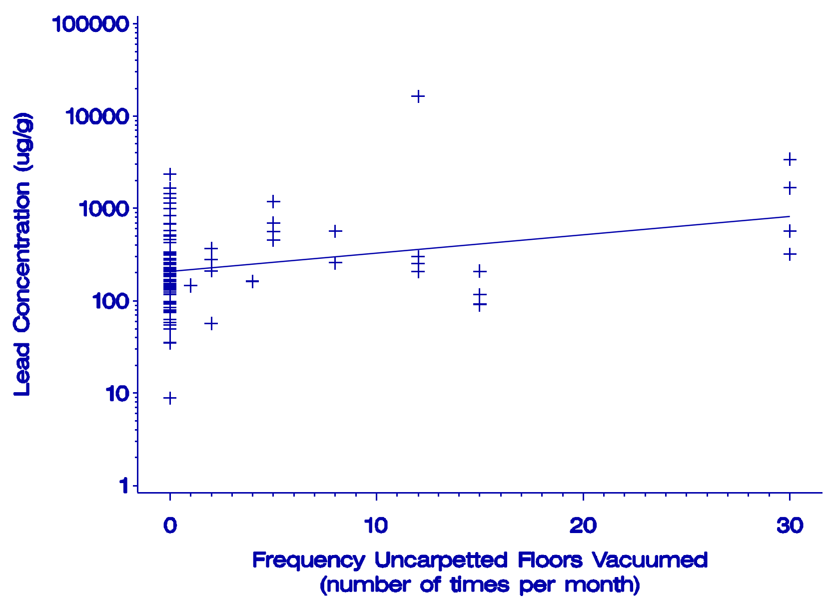


Figure 4-11. Exterior entryway dust lead concentration

discussed above were excluded the factor was not observed to be significant. However, in the results presented, data from these two houses were included.

There were three houses at which a resident was employed in an occupation where welding was performed. Lead concentrations and dust loadings were significantly higher at these houses than at others. Two of these were abated and one was an unabated house.

4.2.4 <u>Non-Abatement Effects by Sample Type</u>

<u>Dust Samples</u>

Air Ducts. One hundred nine (109) air duct samples were collected. Two of the 109 air duct samples were taken from baseboard-type heating elements and two others were taken from cold-air returns. There were differences between results of these and other types of samples. To avoid making unsubstantiated conclusions about the impact of these deviations and to simplify interpretation, these four samples were deleted from the analyses. Due to common difficulties in removing covers from air ducts, 46 of 109 samples were taken from the exterior fins or grates covering the air ducts. The remaining 59 samples were taken from inside the air ducts. This had a significant impact on the results. The substrate condition was also observed to have a significant effect. Table 4-9 presents estimates of these effects.

Lead loadings were substantially lower in samples taken from the exterior grates. This was mainly due to significantly lower dust loadings, but concentrations were also slightly lower (though not significantly lower). One air duct was damaged and three air ducts had peeling substrates. Lead levels were significantly higher on the damaged and peeling substrates.

Lead concentrations were lower in houses where there was frequent wet-mopping of uncarpeted floors. In houses where the window stools were frequently dusted, there were higher concentrations in the air ducts.

Window Channels. Substrate and condition of substrate were important factors associated with lead levels in window channels. Thirty-three (33) of the channels were made of metal; 44 were made of wood. Differences in lead concentrations and lead loadings on these were significant. Lead loadings were almost 40% lower than average on metal. Conditions of these substrates were primarily either good or peeling. These differences were shown to have an association with lead concentrations. On peeling surfaces, concentrations were almost three times as high as on channels which were intact.

Twenty-seven (27) percent of the window channel samples were taken with the small nozzle attached to the vacuum. Lead loadings were estimated to be three and one-half times higher in these samples.

Window Stools. Significantly higher lead loadings were observed in houses where a resident wore work clothes home from an occupation with potential lead exposure. Lead concentrations in these houses were not significantly higher, but dust loadings were higher.

Interior Entryway. The most influential variable for lead loading appeared to be substrate, with highest loadings observed in samples taken from carpets. Most of the samples were taken from carpet and linoleum with fewer taken on tile and wood floors. Lead loadings were about six times higher on carpet than on linoleum; three times higher on carpet than on wood; and more than 30 times higher on carpet than on tile. The differences were attributed to greater levels of dust retained by the carpet, since there were no significant differences in concentrations among these substrates.

There were somewhat higher lead loadings and concentrations in homes where there was more frequent vacuuming of uncarpeted floors. The difference in lead concentration was about 6 percent for a 50 percent increase in frequency of vacuuming. Higher concentrations were observed in houses where paint removal was recently done. Lower loadings and concentrations were observed in houses where there were more children between the ages of 7 and 17.

Exterior Entryway (Dust). Aside from abatement, only frequency of vacuuming uncarpeted floors was found to be significantly related to levels of lead in the dust outside the entryways to these homes. Lead concentrations were found to be higher in houses where vacuuming of uncarpeted floors was more frequent. Dust levels were lower in these houses. These two relationships combined to yield no association between the factor and lead loading.

Floor (Wipe). Substrate was found to be an important determinant in lead loading for wipe samples. Most samples were collected from linoleum (38) and wood (18) floors. Loadings were about 50 percent higher on wood than on linoleum. (Lead loadings on wood were also higher than on linoleum for floor samples collected by vacuum.) Also, rented homes had lead loadings on floors 42 percent lower than those in owner-occupied homes.

Floor (Vacuum). Perhaps the most significant factor associated with floor lead levels was substrate. Most of the samples were taken on carpet (84), linoleum (85), wood (40), and tile (20). Of these, dust loading was greatest on carpets. Lead concentrations were similar on carpet, linoleum, and tile, but on wood they were over two times as large. Hence the highest lead loadings (excluding four samples taken on concrete) were on wood. Lead loadings were about 50 percent higher on wood than on carpet, and were much lower on linoleum and tile.

In houses where uncarpeted floors were vacuumed more frequently, there were higher lead concentrations. Homes in which a resident was employed in welding had lead concentrations almost four times as large as in homes which did not. In those same houses, dust loadings were more than twice as high, contributing to lead loadings more than nine times as great.

The presence of pets was also found to be significantly related with the concentrations of lead in the dust on the floors of these houses. Lead concentration was 18 percent lower and dust loading was 27 percent higher in these houses. Lead loading was about the same. Thus, owning pets may increase the amount of dust present without significantly influencing the amount of lead.

Soil Samples

Entryway Soil. House age was found to be related to lead concentration in soil outside the entryways of these houses. Lead concentrations were lower in newer houses. The relative difference in soil lead concentration at the entryways of these houses was about 10 percent for every ten years difference in age.

There was also a difference observed between lead concentrations in entryway soil at houses where a resident brought work clothes home from an occupation with potential lead contamination. Homes with these types of residents had lead concentrations about 34 percent lower.

Foundation Soil. Several factors were significantly associated with lead concentrations in foundation soil. Most of the significant non-abatement factors were related to ownership of the home. Older houses had higher concentrations. A ten-year difference in age was associated with a difference of 23 percent in lead concentrations near the foundation. However, lead levels were lower in houses where the residents have lived longer since abatement. A house occupied one month longer than the nominal period of 18 months had an estimated 6% lower lead level. Controlling for the other factors, lead concentrations around homes rented by their residents were only about a third as high as around those homes owned by their residents.

Another factor found to be significantly associated with lower lead concentrations was recent paint removal at the house.

Also, lead concentrations were almost twice as high around houses where a resident was employed in a welding occupation.

Boundary Soil. Lead concentrations in boundary soil were significantly associated with the age of the house. An increase in age of 10 years was associated with an increase in lead concentration of about 20 percent. From Figure 4-10, it is apparent that logarithm of lead concentrations increased fairly linearly with age of house.

Three homes were observed in which a resident was employed in an occupation involving paint removal. In these homes, lead concentration was significantly lower (60 percent lower). There was also a significant association found between lead concentration in boundary soil and the frequency with which pipes or electronic parts were soldered in the last 6 months. Levels were significantly higher in houses where soldering activity occurred. Finally, houses where a resident was employed in an occupation involving salvage had higher boundary lead concentrations.